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Mortality of Arctic Grayling Captured and Released With Sport Fishing Gear

by

Robert A. Clark

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ABSTRACT

In three experiments, the mortality rate of Arctic grayling *Thymallus arcticus* caught with three commonly used sport fishing gears was estimated. In two single-capture experiments there were no significant differences in mortality rates caused by baited single-hooks, treble-hook lures, and single-hook flies. Mortality rates in these experiments ranged from 0.0 to 1.4 percent during a 48-hour period and no gear type caused significantly ($\alpha = 0.10$) greater mortality than occurred with control fish. In one multiple-capture experiment, Arctic grayling subjected to as many as five captures over a 61 day period suffered no significant mortality. No cumulative effect of multiple catching and releasing was detected for up to five captures. In all experiments there was a significant relation between hook placement and the level of bleeding observed after capture. Arctic grayling caught in the gill, gullet, eye, or cheek had a higher incidence of bleeding than those caught in the jaw or mouth. The implications of these results are that bait restrictions and single-hook restrictions may be unnecessary for a successful catch-and-release or length-limit regulation. However, further research is recommended to quantify the relation between hook placement and the type of bait used.

KEY WORDS: catch-and-release, mortality, baited single-hook, treble-hook lure, single-hook fly, hook placement, bleeding, Chatanika River, Clear Hatchery, Harding Lake, Arctic grayling, *Thymallus arcticus*.

INTRODUCTION

Restrictive sport fishing regulations for Arctic grayling *Thymallus arcticus* in interior Alaska are founded on the assumption that fish suffer low mortality when caught and released by anglers (Clark 1987). However, only a single attempt to quantify the mortality rates of caught and released Arctic grayling has been made to date. Falk and Gillman (1975) looked at the effects of gear, hook type, hook placement, handling time, and amount of bleeding. Unfortunately, the sample sizes in their experiment were not sufficient to correctly test the significance of these variables. They did, however, have an overall mortality rate of approximately 10%.

In this study, three general gears were investigated: single-hook artificial lures, treble-hook artificial lures, and baited single hooks. These gears represent the present range of legal gears used by anglers to catch Arctic grayling in interior waters. If mortality rates of Arctic grayling caught with these three gears could be quantified, then restrictive regulations could incorporate changes to accommodate the capture and release of sub-legal fish (minimum length-limit) or the entire stock (catch-and-release fishing).

The specific objectives of this research project were:

1) to test the hypothesis that there is no significant mortality suffered by Arctic grayling caught once with single-hook artificial lures, treble-hook artificial lures, and single baited hooks;

2) if the null hypothesis in objective 1 is rejected for at least two gears, then test the hypothesis that gears that produce significant mortality rates in Arctic grayling produce equal mortality rates; and,

3) to test the hypothesis that repeated catching and releasing of Arctic grayling has no cumulative effect on mortality rate beyond that expected from independent effects of separate capture.

These objectives were addressed in two different experiments. The first experiment tested for differences in mortality rate among three gears with Arctic grayling caught once (single-capture experiment). This experiment was performed twice, once at the Chatanika River and once at Clear Hatchery. The second experiment tested for a cumulative effect of multiple catching and releasing of Arctic grayling (multiple-capture experiment) and was conducted at Harding Lake.

METHODS

Methods of Capture and Handling

Gears used to capture Arctic grayling and methods of handling were similar in both the single-capture and multiple capture experiments. The three general gears were:

1) a size 12 single-egg hook that was baited with either a single salmon egg, a live grasshopper, a single kernel of canned corn, or a single pellet of commercial fish food (5 mm size);

2) a size 12 treble hook attached to either a number 1 Mepps™ spinner or a white rubber mini-jig body; and,

3) a size 12 single-hook fly tied as either a brown nymph (wet fly), Salcha pink (dry fly), or mosquito (dry fly).

All gears were fished on 3 kg test (approximately 6 lb test) monofilament line from either a fly rod or spinning rod. When hooked, each fish was played for approximately 30 sec before being removed from the hook. If fish were hooked in the gullet, the line was cut. Fish were immediately transferred to a 19ℓ (5 gal) bucket.

All Arctic grayling captured were measured to the nearest 1 mm fork length (FL) and the location of the hook in the fish was noted with criteria adapted from Falk and Gillman (1975; see also Figure 1). The level of bleeding was determined using a four-point scale (adapted from Falk and Gillman 1975):

0) none: no evidence of any external bleeding;

1) slight: small amount of external bleeding, generally localized near the point of entry of the hook;

2) moderate: greater amount of external bleeding, but generally localized near the point of entry of the hook; and,

3) severe: copious amount of blood, generally staining the water in the holding bucket and generally surrounding and obscuring the point of entry of the hook.

Time of capture to the nearest 1 min was also recorded.

Single-Capture Experiments

There were two separate single-capture experiments performed to test the hypothesis that there is no significant mortality of Arctic grayling captured with the three gears. The first experiment was conducted under field conditions on the Chatanika River. There was no control for this experiment, thus a second single-capture experiment was conducted in an outdoor raceway at Clear Hatchery, utilizing a dip net to collect control fish.

Experiment 1 - Chatanika River:

During 21 through 23 August 1990 the first of two single-capture experiments was conducted on the Chatanika River in the vicinity of the Elliott Highway bridge. The area fished included a 4.8 km section of the Chatanika River upstream of the Elliott Highway bridge. Daytime water temperature averaged 7.5°C during the experiment. Three treatments were used: 1) either salmon eggs or a live grasshopper on single hooks; 2) a number 1 Mepps spinner used

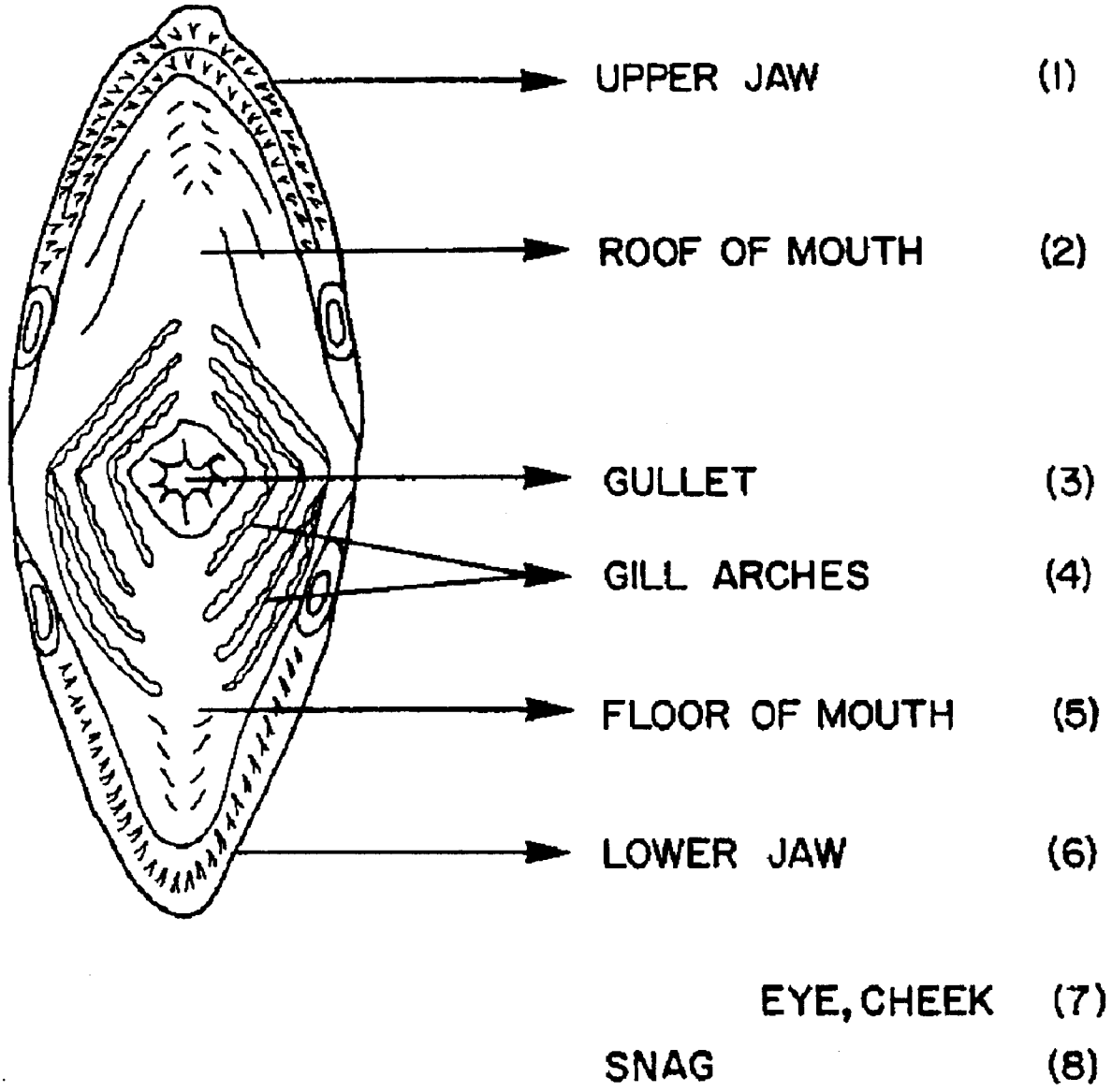

Figure 1. Description of hook placements used in the single-capture and multiple-capture experiments in 1990 and 1991 (adapted from Falk and Gillman 1975).

as a treble-hook lure; and, 3) a brown nymph used as a single-hook fly. Treatments did not contain a control. Two biologists and one fishery technician served as anglers in this experiment. Sixty (60) Arctic grayling were captured with each of the gears for (180 fish in all). Because fish captured from the Chatanika River are from a naturally occurring stock, each Arctic grayling captured was identified by attaching an individually numbered Floy FTSL-73 streamer tag to the anterior insertion of the dorsal fin, just under the dorsal musculature. The streamer tag was then tied (two overhand knots) to prevent loss of the tag during the holding period. Captured fish were handled as described above and then transferred to 0.6 m × 1.0 m holding tank that was continuously aerated with water from the river. Within 6.5 hours of capture, all fish were transferred to a 1.2 m × 2.4 m holding pen located in a backwater area of the river. All captured fish were held in the holding tank and pen for a minimum of 48 hours. Only fish that died within 48 hours were included in estimates of mortality. All remaining fish that were alive after 48 hours were released back into the Chatanika River.

Mortality rate was defined as the number of Arctic grayling that died within 48 hours of capture (by gear type) divided by the total number captured with each gear type:

$$\hat{m}_i = \frac{X_i}{n_i} \qquad (1)$$

where:

m_i = the mortality rate of fish that were caught with gear *i*;

n_i = the number of fish that were caught with gear *i*; and,

X_i = the number of fish that were caught with gear *i* and died.

The standard error of this rate was estimated by (Zar 1984):

$$SE[\hat{m}_i] = \left[\frac{\hat{m}_i \ (1 - \hat{m}_i)}{(n_i - 1)} \right]^{1/2} \qquad (2)$$

To test the first hypothesis (objective 1), binomial confidence intervals were calculated for each estimate of mortality due to each of the gears. The probability of a Type I error (α) was adjusted to 0.03, so that an overall α=0.10 could be maintained for the three comparisons. Binomial confidence intervals were calculated as (Zar 1984):

$$LCI_i = \frac{X_i}{X_i + (n_i - X_i + 1) \ F_{\gamma 1, \gamma 2}} \qquad (3)$$

and,

$$UCI_i = \frac{(X_i + 1)\, F_{\gamma 1', \gamma 2'}}{n_i - X_i + (X_i + 1)\, F_{\gamma 1', \gamma 2'}} \quad (4)$$

where:

LCI_i = lower 90% confidence interval for the mortality rate of gear *i*;

UCI_i = upper 90% confidence interval for the mortality rate of gear *i*;

$F_{\gamma 1, \gamma 2}$ = probability from the F distribution with γ_1, γ_2 degrees of freedom where:

$$\gamma_1 = 2(n_i - X_i + 1); \text{ and,} \quad (3a)$$
$$\gamma_2 = 2X_i; \text{ and,} \quad (3b)$$

$F_{\gamma 1', \gamma 2'}$ = probability from the F distribution with $\gamma_{1'}, \gamma_{2'}$ degrees of freedom where:

$$\gamma_{1'} = 2(X_i + 1); \text{ and,} \quad (4a)$$
$$\gamma_{2'} = 2(n_i - X_i). \quad (4b)$$

Falk and Gillman (1975) estimated an overall mortality rate of 10% for Arctic grayling in Great Slave Lake. With a sample size of 60 fish for each gear, differences in mortality rate of 10% or greater are detectable, so that estimates of mortality rates from using each of the three gears were tested with a one-tailed binomial test (Zar 1984). The null hypothesis was: each of the gears caused mortality of Arctic grayling at a rate that is less than or equal to 0.10.

The length frequency distributions of Arctic grayling captured with each of the gears were compared with the Anderson-Darling k-sample test (Scholz and Stephens 1987). Data concerning the frequency of hook placement and level of bleeding were summarized for each of the gears. There were two major categories of hook placement (hooked in the gullet, gill, or eye area; and, not hooked in any of these areas) and two levels of bleeding (no bleeding and some bleeding). These data were then tested for independence of either hook placement or level of bleeding on the gears used with contingency tables (Zar 1984). If the hypotheses of independence of hook placement or level of bleeding failed to be rejected ($P > 0.10$), then hook placement and level of bleeding data were pooled among gears and a test of independence of the level of bleeding on hook placement was performed.

Although this experiment allowed for a meaningful comparison of mortality rates among the three gears, it did not control for handling induced mortality (from measuring, tagging, transport, and holding) that would not be expected from angler caught fish. No suitable control is available in a field experiment of this type. Therefore, the second single-capture experiment was designed to control for handling-induced mortality by using a hatchery raceway as an analogy to a stream.

Experiment 2 - Clear Hatchery:

During 15 through 17 April 1991 the second of two single-capture experiments was conducted at Clear Hatchery (operated by the Fisheries Rehabilitation, Enhancement, and Development Division of the Alaska Department of Fish and Game) on Clear Air Force Station near the town of Anderson. Approximately three weeks prior to the start of the experiment, 1,500 age 1 Arctic grayling that had been reared in an indoor raceway were tagged with individually numbered Floy FD-67 anchor tags. Mortality after tagging was negligible (six fish died). One week prior to the experiment a random sample of 300 tagged Arctic grayling were placed in an outdoor raceway adjacent to the hatchery. The outdoor raceway had two equal compartments (the fish were all placed in one compartment), each 6.1 m × 2.4 m and 1.5 m deep. Water temperature was held constant at 12.7°C during the experiment, and the fish were not fed during the experiment.

Three treatments were used: 1) either salmon eggs or a single kernel of canned corn on single hooks; 2) a number 1 Mepps™ spinner or a size 12 treble hook attached to a rubber mini-jig; and, 3) a brown nymph or Salcha pink were used as a single-hook fly. In addition, a dip net was used to capture fish for the control. Two biologists performed all of the fishing for this experiment. The three gears were used in rotation, capturing the first fish with a randomly selected gear and then sequentially using each of the other two gears to capture the second and third fish. The control sample was then taken (fourth fish), and the process repeated until 60 fish were captured with each gear and the control gear (240 fish total). Captured fish were handled as described above and then transferred back to a separate compartment in the indoor raceway. All captured fish were held in the holding tank and pen for a minimum of 48 hours. Only fish that died within 48 hours were included in estimates of mortality rates.

All analyses and hypotheses tested for the Chatanika River experiment were repeated for the Clear Hatchery experiment, with the sole exception of adding a control to the experimental design.

A multiple-capture experiment was started in the outdoor raceway at Clear Hatchery (60 fish remaining in the raceway after 240 fish were removed), but was terminated after only 75 captures of the 60 fish. No fish had died within 48 hours of capture. The experiment was terminated because few captures could be made in any single fishing bout. For example, in the first 7.5 hour bout of fishing on the group of 60 fish, 27 fish were captured for the first time. The next day, a fishing bout of 5.0 hours resulted in a catch of nine fish. At these capture rates it would have conservatively taken 121 hours of fishing (approximately 16 7.5-hour days) to capture 60 fish 350 times (the desired sample size). Only six days were allocated to complete the experiment and hatchery personnel needed the outdoor raceway for other projects. Since learning behavior may have influenced catch rates, a second multiple-capture experiment was designed with two months allotted to collect sufficient data.

Multiple-Capture Experiment

During 25 June through 24 August 1991 a multiple-capture experiment was conducted at Harding Lake in net-pens (for a description of the net-pens see Clark, et al. 1991). The design incorporated multiple holding pens so that the fish could be separated by the number of times they had been captured, allowing for fish in one pen to recover from a fishing bout while fish in a second pen could be captured.

One-hundred and seventy seven of the remaining 1,200 Arctic grayling from the experiment at Clear Hatchery, were placed in one of six 3.6 m × 3.6 m net-pens that were 3.6 m deep. Fish were fed minimal rations during the experiment, and there were numerous zooplankters from the lake in all of the pens. Surface water temperature ranged from 14.0°C (mid August) to 23.5°C (mid July) during the experiment.

Three standard gears were used: 1) either salmon eggs or a single pellet of commercial fish food (5 mm size) were baited on single hooks; 2) a number 1 Mepps™ spinner and a size 12 treble hook attached to a rubber mini-jig; and, 3) a brown nymph was used as a fly with a single-hook. Because none of the gears produced significantly higher mortality rates in earlier experiments, the most efficient gear type (highest catch rate) was generally used to capture fish. Ten people (two biologists and eight fishery technicians) served as anglers during the experiment, although no more than four "anglers" were fishing at any one time. Captured fish were immediately sampled as described above and then placed in the adjacent net-pen. At the end of the experiment each of the six pens contained fish that had only been captured a specific number of times.

RESULTS

Single-Capture Experiments

The central result of both single-capture experiments was that no significant differences in mortality rate of Arctic grayling among gears was observed. Moreover, the mortality rate caused by each of the gears was not significantly different from the control gear, nor was mortality rate significantly greater than 10%. However, a significant relation between hook placement and the level of bleeding observed in captured Arctic grayling was detected. The following sections detail results of the two single-capture experiments.

Experiment 1 - Chatanika River:

Mortality after 48 hours of holding consisted of one fish caught with a fly. The fish was caught in the gullet and slight bleeding was detected. The fish was dead within 2 hours of capture. Mortality rate of Arctic grayling caught with baited single-hooks was 0.0%, caught with treble-hooks was 0.0%, and caught with single-hook fly 1.7%. Using 90% confidence intervals, there were no significant differences in mortality rate of the three gears. Moreover, no gear type had a mortality rate significantly greater than 10% (single-tailed binomial test, $P = 0.998$).

No significant difference in size distribution of Arctic grayling caught with the three gears was detected (Anderson-Darling k-sample test: T_{kn} = -0.852, $P > 0.10$; Figure 2), so that differences in hook placement or bleeding among gears could not be attributed to differences in the sizes of fish caught. Sizes of Arctic grayling captured (all gears pooled) ranged from 125 mm to 309 mm FL with a mean of 202 mm FL (SD = 35 mm FL).

Hook placement tended to be similar among the three gears, with hooking in the upper jaw and the roof of the mouth (Figure 1) representing 51.8% to 68.3% of the captures (Table 1). When hook placement data were collapsed into two general categories, there was no significant difference ($P > 0.50$) in the distribution of hook placement among the three gears (Tables 1 and 2). The majority (83.3% to 91.5%) of Arctic grayling caught with the three gears exhibited no discernable bleeding (Table 3). When bleeding data were collapsed into two general categories, there was no significant difference ($0.10 < P < 0.50$) in the distribution of bleeding caused by the three gears (Tables 2 and 3). Fish caught in either the gill, gullet, eye, or cheek had a significantly greater ($P < 0.005$) likelihood of bleeding than those fish not so caught (Tables 2 and 4).

Experiment 2 - Clear Hatchery:

Mortality after 48 hours consisted of one fish caught with a fly. The fish was caught in the gullet and no bleeding was detected. None of the control fish had died after 48 hours, resulting in an estimate of handling mortality of 0.0%. Mortality rate of Arctic grayling caught with a baited hook was 0.0%, caught with treble-hook was 0.0%, and caught with single-hook flies was 1.7%. Using 90% confidence intervals, there were no significant differences in mortality rates of the three gears. Moreover, no gear had a mortality rate significantly greater than 10% (single-tailed binomial test, $P = 0.998$).

No significant difference in size distribution of Arctic grayling caught with the three gears was detected (Anderson-Darling k-sample test: T_{kn} = -0.736, $P > 0.10$; Figure 3), so that differences in hook placement or bleeding among gears could not be attributed to differences in the sizes of fish caught. However, the size distribution of the control sample was significantly different from the size distribution of fish caught with the three gears (Anderson-Darling k-sample test: $T_{kn} = 5.086$, $P < 0.01$; Figure 3). Sizes of all Arctic grayling captured ranged from 132 mm to 254 mm FL with a mean of 206 mm FL (SD = 23 mm FL). Fish in the control sample ranged from 126 mm to 250 mm FL with a mean of 199 mm FL (SD = 25 mm FL).

Hook placement tended to be similar for all three gears, with hooking in the upper jaw and the roof of the mouth (Figure 1) representing 63.3% to 75.0% of the captures (Table 5). When hook placement data were collapsed into two general categories, there was no significant difference ($P > 0.50$) in the distribution of hook placement among the three gears (Tables 2 and 5). The majority (76.7% to 95.0%) of Arctic grayling caught with the three gears exhibited no discernable bleeding (Table 6). However, when bleeding data were collapsed into two general categories, treble-hooks produced a higher incidence of bleeding than either bait or flies ($0.01 < P < 0.025$; Tables 2

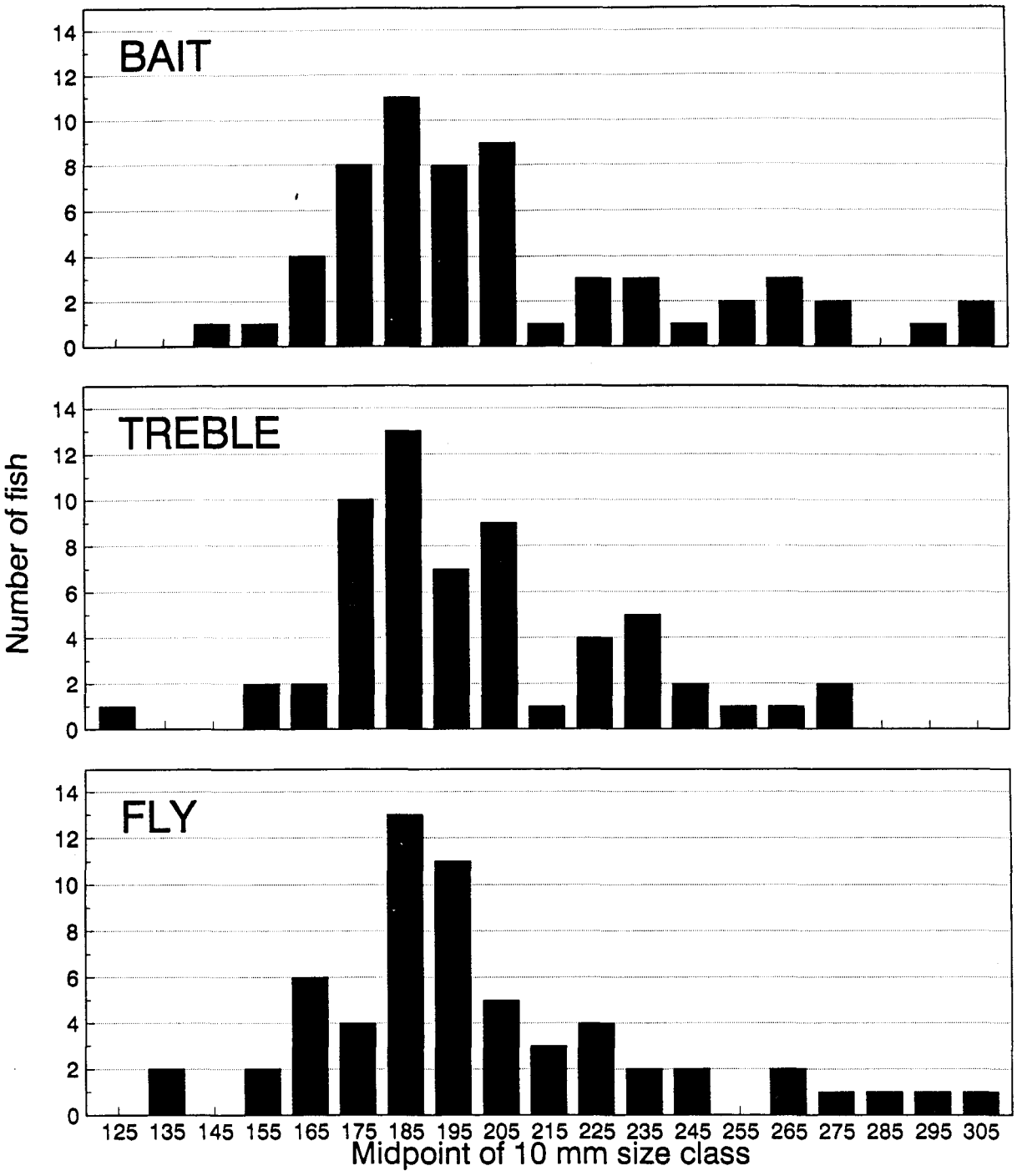

Figure 2. Size distributions of Arctic grayling caught with baited hooks, treble hooks, and flies during the catch-and-release experiment at the Chatanika River, 23 - 25 August 1990.

Table 1. Summary of hook placement by gear for Arctic grayling captured in the Chatanika River, 21 - 23 August 1990.

	Gear					
	Bait[a]		Treble[b]		Flies[c]	
Placement	n	%	n	%	n	%
Upper jaw (1)	21	35.0	25	41.7	20	35.7
Roof of mouth (2)	20	33.3	14	23.3	9	16.1
Gullet (3)	6	10.0	1	1.7	1	1.8
Gill arches (4)	0	0.0	1	1.7	0	0.0
Floor of mouth (5)	2	3.3	3	5.0	2	3.6
Lower jaw (6)	8	13.3	11	18.3	19	33.9
Eye or cheek (7)	3	5.0	4	6.7	5	8.9
Snagged (8)	0	0.0	0	0.0	0	0.0
Other (9)	0	0.0	1	1.7	0	0.0
Jaw/mouth/snag[d]	51	85.0	54	90.0	50	89.3
Gill/gullet/eye[e]	9	15.0	6	10.0	6	10.7
Total	60	100.0	60	100.0	56	100.0

[a] Bait is a size 12 single hook baited with either a single salmon egg or a grasshopper (egg hooks).
[b] Treble is a Mepps™ spinner with a #1 blade and size 12 treble hook.
[c] Flies is a single hook fly (either a size 12 brown nymph or mosquito).
[d] Hook placements 1, 2, 5, 6, 8, or 9 of Falk and Gillman (1975).
[e] Hook placements 3, 4, or 7 of Falk and Gillman (1975).

Table 2. Summary of hypothesis tests to evaluate the independence of hook placement and level of bleeding on the gear used, and evaluate the independence of hook placement on the level of bleeding during catch-and-release of Arctic grayling in the Chatanika River, at Clear Hatchery, and at Harding Lake, 1990 and 1991.

Study site	Hypothesis tested	χ^2	df[a]	P
Chatanika River	Hook placement × gear	0.83	2	$P > 0.50$
	Bleeding × gear	1.80	2	$0.10 < P < 0.50$
	Hook × bleeding	26.67	1	$P < 0.005$
Clear Hatchery	Hook placement × gear	3.84	2	$0.10 < P < 0.50$
	Bleeding × gear	8.94	2	$0.01 < P < 0.025$
	Hook × bleeding[b]	3.56[c]	1	$0.05 < P < 0.10$
Harding Lake[d]	Hook placement × gear	2.13[e]	2	$0.10 < P < 0.50$
	Bleeding × gear	1.23	2	$0.10 < P < 0.50$
	Hook × bleeding	14.93	1	$P < 0.005$

[a] Reduced degrees of freedom are due to pooling data on hook placement (from nine areas to two general areas) or on level of bleeding (from four levels to two levels) or both.
[b] Data for baited hooks and flies were pooled before this test.
[c] One sparse cell in this table (expected value less than five, but not less than one).
[d] Hypothesis tests were performed with all captures pooled.
[e] Two sparse cells in this table (expected values less than five, but not less than one).

Table 3. Summary of bleeding by gear for Arctic grayling captured in the Chatanika River, 21 - 23 August 1990.

	Gear					
	Bait[a]		Treble[b]		Flies[c]	
Bleeding[d]	n	%	n	%	n	%
None (0)	52	86.7	54	91.5	50	83.3
Slight (1)	4	6.7	4	6.8	9	15.0
Moderate (2)	3	5.0	0	0.0	1	1.7
Severe (3)	1	1.7	1	1.7	0	0.0
No bleeding	52	86.7	54	91.5	50	83.3
Some bleeding[e]	8	13.3	5	8.5	10	16.7
Total	60	100.0	59	100.0	60	100.0

[a] Bait is a size 12 single hook baited with either a single salmon egg or a grasshopper (egg hooks).
[b] Treble is a Mepps™ spinner with a #1 blade and size 12 treble.
[c] Flies is a single hook fly (either a size 12 brown nymph or mosquito).
[d] Bleeding levels are from Falk and Gillman (1975).
[e] Some bleeding is bleeding levels 1, 2, or 3 of Falk and Gillman (1975).

Table 4. Interaction between hook placement and bleeding in Arctic grayling captured by baited hooks, treble hooks, and flies in the Chatanika River, 21 - 23 August 1990.

	Hook placement			
	Jaw/mouth/snag[a]		Gill/gullet/eye[b]	
Bleeding	n	%	n	%
No bleeding	142	92.2	11	52.4
Some bleeding[c]	12	7.8	10	47.6
Total	154	100.0	21	100.0

[a] Hooked in the upper jaw, roof of mouth, floor of mouth, lower jaw, or snagged.
[b] Hooked in the gill arches, gullet, eye, or cheek.
[c] Some bleeding describes slight, moderate, or severe bleeding of Falk and Gillman (1975).

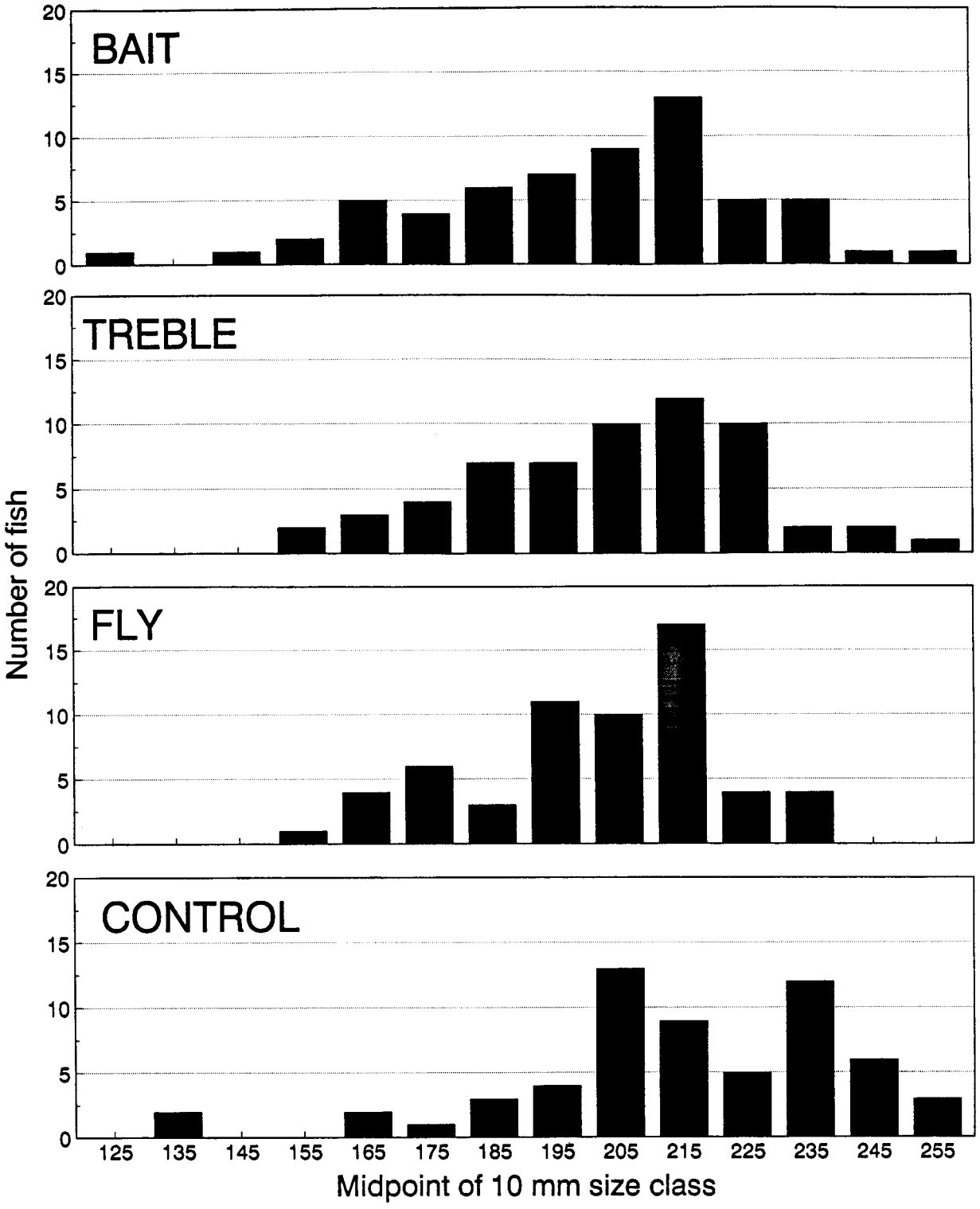

Figure 3. Size distributions of Arctic grayling caught as controls (dip net), or with baited hooks, treble hooks, and flies during the catch-and-release experiment at Clear Hatchery, 15 - 17 April 1991.

Table 5. Summary of hook placement by gear for Arctic grayling captured at Clear Hatchery, 15 - 17 April 1991.

	Gear					
	Bait[a]		Treble[b]		Flies[c]	
Placement	n	%	n	%	n	%
Upper jaw (1)	35	58.3	33	55.0	37	61.7
Roof of mouth (2)	6	10.0	5	8.3	8	13.3
Gullet (3)	1	1.7	0	0.0	3	5.0
Gill arches (4)	1	1.7	0	0.0	1	1.7
Floor of mouth (5)	0	0.0	1	1.7	1	1.7
Lower jaw (6)	3	5.0	5	8.3	5	8.3
Eye or cheek (7)	4	6.7	2	3.3	4	6.7
Snagged (8)	10	16.7	14	23.3	1	1.7
Other (9)	0	0.0	0	0.0	0	0.0
Jaw/mouth/snag[d]	54	90.0	58	96.7	52	86.7
Gill/gullet/eye[e]	6	10.0	2	3.3	8	13.3
Total	60	100.0	60	100.0	60	100.0

[a] Bait is a size 12 single hook baited with either a single salmon egg or a single kernel of canned corn (egg hooks).
[b] Treble is a Mepps™ spinner with a #1 blade and size 12 treble or a rubber mini-jig fitted with a size 12 treble hook.
[c] Flies is a single hook fly (either a size 12 brown nymph or mosquito).
[d] Hook placements 1, 2, 5, 6, 8, or 9 of Falk and Gillman (1975).
[e] Hook placements 3, 4, or 7 of Falk and Gillman (1975).

Table 6. Summary of bleeding by gear for Arctic grayling captured at Clear Hatchery, 15 - 17 April 1991.

	Gear					
	Bait[a]		Treble[b]		Flies[c]	
Bleeding[d]	n	%	n	%	n	%
None (0)	53	88.3	46	76.7	57	95.0
Slight (1)	4	6.7	12	20.0	3	5.0
Moderate (2)	3	5.0	2	3.3	0	0.0
Severe (3)	0	0.0	0	0.0	0	0.0
No bleeding	53	88.3	46	76.7	57	95.0
Some bleeding[e]	7	11.7	14	23.3	3	5.0
Total	60	100.0	60	100.0	60	100.0

[a] Bait is a size 12 single hook baited with either a single salmon egg or a single kernel of canned corn (egg hooks).
[b] Treble is a Mepps™ spinner with a #1 blade and size 12 treble or a rubber mini-jig fitted with a size 12 treble hook.
[c] Flies is a single hook fly (either a size 12 brown nymph or mosquito).
[d] Bleeding levels are from Falk and Gillman (1975).
[e] Some bleeding is bleeding levels 1, 2, or 3 of Falk and Gillman (1975).

and 6). When data on hook placement and bleeding for baited hooks and flies were pooled, fish caught in either the gill, gullet, eye, or cheek had a significantly greater ($0.05 < P < 0.10$) likelihood of bleeding than those fish not so caught (Tables 2 and 7). There appeared to be a relation between hook placement and level of bleeding for treble-hooks, but the number of fish caught in either the gill, gullet, eye, or cheek was too small (2 fish) for a statistical comparison with fish not so caught (Table 8).

Multiple-capture Experiment

Of the original 147 fish, 77 fish were caught at least once, 72 fish were caught at least twice, 61 fish were caught at least three times, 46 fish were caught at least four times, and 23 fish were caught five times. Mortality during the entire experiment was restricted to one fish that had been caught twice. The fish was first caught on 25 June with a treble-hook, was hooked in the upper jaw and had no discernable bleeding. On 10 July, 15 days later, the fish was caught again in the upper jaw with a baited hook and had no discernable bleeding. The fish was found dead on 19 July, nine days later. None of the remaining 70 fish that had never been caught died during the experiment. A cumulative effect of multiple-capture on mortality rate of Arctic grayling was not observed during this experiment. Mortality rate of fish captured two times was 1.4%; estimated mortality rates for all other treatments was 0.0%. The experiment lasted 61 days.

Of the 279 "captures", 194 occurred with baited hooks, 47 with treble-hooks, and 34 with flies. Gear type was not recorded for four of the 279 captures. Sizes of Arctic grayling captured at least once (all gears pooled) ranged from 160 mm to 256 mm FL with a mean of 216 mm FL (SD = 21 mm FL; see also Figure 4). Without accounting for fish growth, there appeared to be very little change in the size distribution of fish as the experiment progressed and fish were moved from one pen to the next (Figure 4).

Hook placement was similar among the three gears, with hooking in the upper jaw and the roof of the mouth (Figure 1) representing 51.5% to 79.8% of the captures (Table 9). When hook placement data were collapsed into two general categories, there was no significant difference ($0.10 < P < 0.50$) in the distribution of hook placement among the three gears (Tables 2 and 9). The majority (79.4% to 85.6%) of Arctic grayling caught with the three gears exhibited no discernable bleeding (Table 10). When bleeding data were collapsed into two general categories, there was no significant difference ($0.10 < P < 0.50$) in the distribution of bleeding caused by the three gears (Tables 2 and 10). After pooling the collapsed hook placement and bleeding data for all gears, fish caught in either the gill, gullet, eye, or cheek had a significantly greater ($P < 0.005$) likelihood of bleeding than those fish not caught in these areas (Tables 2 and 11).

DISCUSSION

Based on three experiments, mortality rates of Arctic grayling caught and released with each of the three gears were significantly lower than previously

Table 7. Interaction between hook placement and bleeding in Arctic grayling captured by baited hooks and flies at Clear Hatchery, 15 - 17 April 1991.

	Hook placement			
	Jaw/mouth/snag[a]		Gill/gullet/eye[b]	
Bleeding	n	%	n	%
No bleeding	99	93.4	11	78.6
Some bleeding[c]	7	6.6	3	21.4
Total	106	100.0	14	100.0

[a] Hooked in the upper jaw, roof of mouth, floor of mouth, lower jaw, or snagged.
[b] Hooked in the gill arches, gullet, eye, or cheek.
[c] Some bleeding describes slight, moderate, or severe bleeding of Falk and Gillman (1975).

Table 8. Interaction between hook placement and bleeding in Arctic grayling captured with treble hooks at Clear Hatchery, 15 - 17 April 1991.

	Hook placement			
	Jaw/mouth/snag[a]		Gill/gullet/eye[b]	
Bleeding	n	%	n	%
No bleeding	45	77.6	1	50.0
Some bleeding[c]	13	22.4	1	50.0
Total	58	100.0	2	100.0

[a] Hooked in the upper jaw, roof of mouth, floor of mouth, lower jaw, or snagged.
[b] Hooked in the gill arches, gullet, eye, or cheek.
[c] Some bleeding describes slight, moderate, severe bleeding of Falk and Gillman (1975).

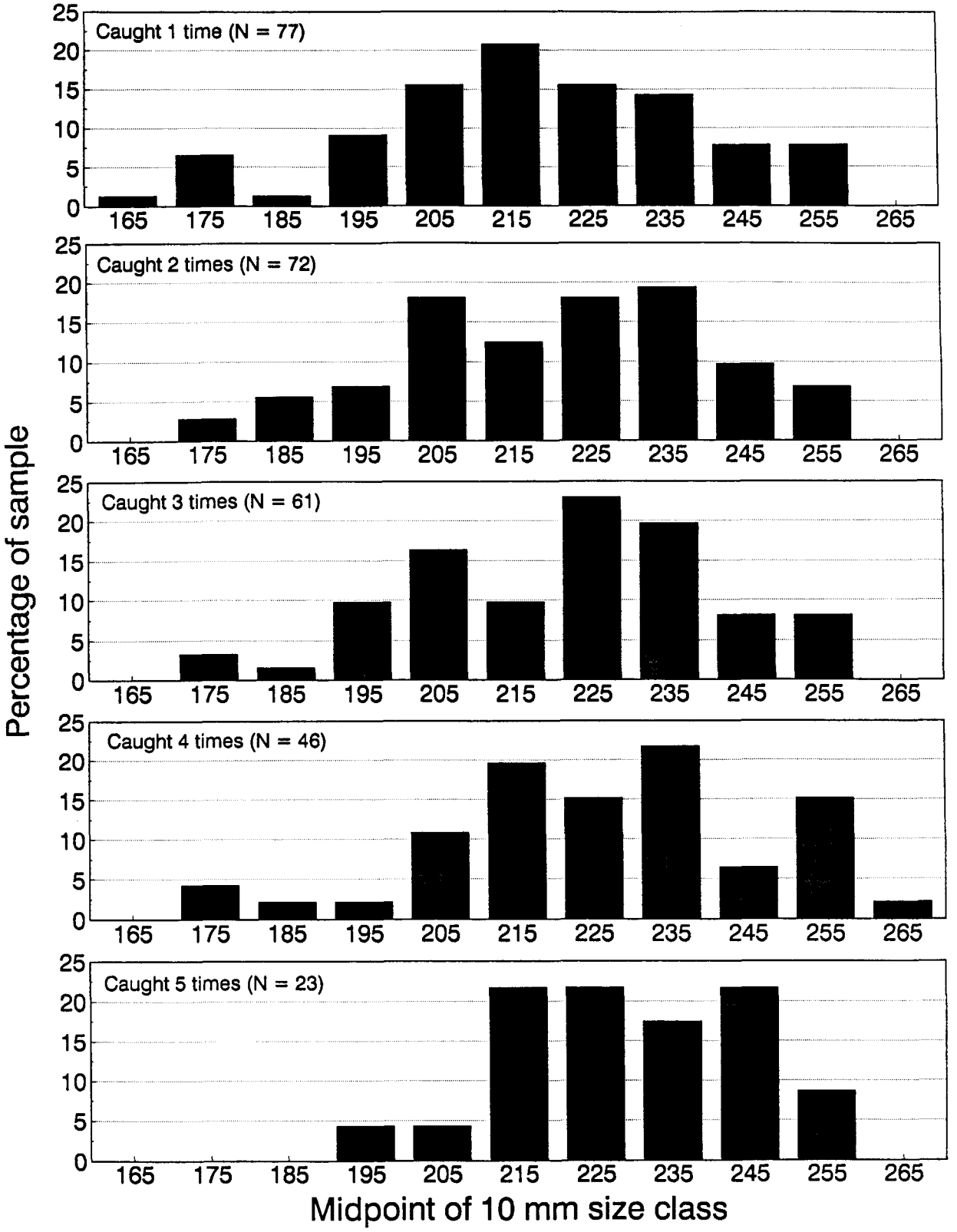

Figure 4. Size distributions of Arctic grayling caught one through five times with baited hooks, treble hooks, and flies during the catch-and-release experiment at Harding Lake, 25 June - 24 August 1991.

Table 9. Summary of hook placement by gear for Arctic grayling captured at Harding Lake, 25 June - 24 August 1991.

	Gear[a]					
	Bait[b]		Treble[c]		Flies[d]	
Placement	n	%	n	%	n	%
Upper jaw (1)	154	79.8	27	57.4	17	51.5
Roof of mouth (2)	18	9.3	2	4.2	1	3.0
Gullet (3)	0	0.0	0	0.0	0	0.0
Gill arches (4)	3	1.5	1	2.1	0	0.0
Floor of mouth (5)	4	2.1	0	0.0	0	0.0
Lower jaw (6)	8	4.1	6	12.8	1	3.0
Eye or cheek (7)	4	2.1	3	6.4	2	6.1
Snagged (8)	2	1.0	8	17.0	12	36.4
Other (9)	0	0.0	0	0.0	0	0.0
Jaw/mouth/snag[e]	186	96.4	43	91.5	31	94.0
Gill/gullet/eye[f]	7	3.6	4	8.5	2	6.0
Total	193	100.0	47	100.0	33	100.0

[a] Results for gears are from all captures pooled.
[b] Bait is a size 12 single hook baited with either a single salmon egg or a single kernel of pelletized commercial fish feed (egg hooks).
[c] Treble is a Mepps™ spinner with a #1 blade and size 12 treble or a rubber mini-jig fitted with a size 12 treble hook.
[d] Flies is a single hook fly (either a size 12 brown nymph or mosquito).
[e] Hook placements 1, 2, 5, 6, 8, or 9 of Falk and Gillman (1975).
[f] Hook placements 3, 4, or 7 of Falk and Gillman (1975).

Table 10. Summary of bleeding by gear for Arctic grayling captured at Harding Lake, 25 June - 24 August 1991.

	Gear[a]					
	Bait[b]		Treble[c]		Flies[d]	
Bleeding[e]	n	%	n	%	n	%
None (0)	166	85.6	38	80.8	27	79.4
Slight (1)	24	12.4	5	10.6	1	2.9
Moderate (2)	1	0.5	2	4.2	3	8.8
Severe (3)	3	1.5	2	4.2	3	8.8
No bleeding	166	85.6	38	80.8	27	79.4
Some bleeding[f]	28	14.4	9	19.2	7	20.6
Total	194	100.0	47	100.0	34	100.0

[a] Results for gears are from all captures pooled.
[b] Bait is a size 12 single hook baited with either a single salmon egg or a single kernel of pelletized commercial fish feed (egg hooks).
[c] Treble is a Mepps™ spinner with a #1 blade and size 12 treble or a rubber mini-jig fitted with a size 12 treble hook.
[d] Flies is a single hook fly (either a size 12 brown nymph or mosquito).
[e] Bleeding levels are from Falk and Gillman (1975).
[f] Some bleeding is bleeding levels 1, 2, or 3 of Falk and Gillman (1975).

Table 11. Interaction between hook placement and bleeding in Arctic grayling captured[a] by baited hooks, treble hooks, and flies at Harding Lake, 25 June - 24 August 1991.

	Hook placement			
	Jaw/mouth/snag[b]		Gill/gullet/eye[c]	
Bleeding	n	%	n	%
No bleeding	224	86.1	6	46.1
Some bleeding[d]	36	13.9	7	53.9
Total	260	100.0	13	100.0

[a] Results for gears are from all captures pooled.
[b] Hooked in the upper jaw, roof of mouth, floor of mouth, lower jaw, or snagged.
[c] Hooked in the gill arches, gullet, eye, or cheek.
[d] Some bleeding level describes slight, moderate, or severe bleeding of Falk and Gillman (1975).

observed by Falk and Gillman (1975). Moreover, there were no detectable cumulative effects of catch-and-release on mortality rate of Arctic grayling. These results imply that minimum length limits and catch-and-release areas currently used for Arctic grayling in interior Alaska are potentially useful methods of protecting a portion or all of the stock. However, very few of the Arctic grayling captured during these experiments were large (greater than 305 mm total length). Further experimentation is recommended to ascertain mortality rates of larger Arctic grayling.

The finding that Arctic grayling caught with a baited single-hook did not suffer significantly higher mortality than single-hook flies or treble-hook lures imply that current restrictions on bait fishing for Arctic grayling may be unnecessary. However, conditions for bait fishing in this study were not similar to those anglers would normally encounter. For example, fish were highly visible during the Clear Hatchery study, thus allowing the anglers to set the hook well before the fish could swallow the bait. Second, baits such as grasshoppers (used on the Chatanika River) float on the surface of the water, allowing the angler to set the hook as a fish strikes the bait. Third, commercial fish food was used as bait during the Harding Lake study; fish often struck this bait as soon as the bait entered the water. All these factors may cause disproportionately less gullet-caught fish than might be expected from fishing a single salmon egg in stained or turbid water. Because of these factors, further experimentation may be warranted.

The level of bleeding was related to placement of the hook in the fish. Fish hooked in the gill, gullet, eye, or cheek were more likely to suffer external bleeding. Yet, external bleeding in Arctic grayling did not result in significant mortality. On the contrary, of the three fish that died during this study, one had slight bleeding and in the other two no bleeding was discerned. Few fish were gullet-hooked during the single-capture experiments (12 fish out of 360), but the two fish that did die during these experiments were gullet-hooked (16.7% of gullet-hooked fish). Seven of the 12 gullet-hooked fish in these experiments were caused by fishing with bait, although none of these seven fish died within 48 hours of capture.

Another implication of these experimental results is that unbaited treble-hooks caused no significant (> 10%) mortality in Arctic grayling. Given these results, single-hook only restrictions currently in force on the upper Chena River may be unnecessary. Alternatively, the only two mortalities resulting from single-capture experiments were caught with single-hook flies. Although this was not a treatment in these experiments, the small size of the hook (size 12) may have been a factor in causing these mortalities (both died after being caught in the gullet).

Results of the multiple-capture study indicate that Arctic grayling may be caught up to five times in a two month period without causing significant cumulative mortality. Although only 23 fish were subjected to the full five captures, if mortality rate had been 5% per capture (no cumulative effect), at least five fish would have died after five captures. Calculating in a different way, if one fish died for every 180 captures (analogous to the single-capture experiments), and the rate doubled for every additional 180 captures, it would have taken more than 10 captures of every one of the 77

fish in the Harding Lake experiment to see a significant amount of mortality (> 10%).

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APPENDIX A
Data File Listing

Appendix A1. Data files[a] used to estimate mortality of Arctic grayling caught and released with sport fishing gear, 1990 and 1991.

Data file	Description
U004ALA0.DTA	Capture data for Arctic grayling used in the catch-and-release experiment at the Chatanika River in 1990.
U987ALA1.DTA	Capture data for Arctic grayling used in the catch-and-release experiment at Clear Hatchery in 1991.
U189ALA1.DTA	Capture data for Arctic grayling used in the catch-and-release experiment at Harding Lake in 1991.

[a] Data files have been archived at, and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.